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Results of a simple intercomparison of natural radioactivity measurements using a 'blue concrete' sample

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Abstract

A simple intercomparison of natural radioactivity and radon emanation factor measurements co-ordinated by the Medical Physics Department of the University of Cantabria UC, Spain, has been carried out during 1998 in the framework of the EU Concerted Action ERRICCA (European Research into Radon in Construction Concerted Action). All the measurements have been made on a 'blue concrete' sample kindly donated by Dr G. Akerblom from the Swedish Radiation Protection Institute. In addition to UC, two other participant laboratories, STUK from Finland and ZVD from the Republic of Slovenia, have contributed to the development of the intercomparison exercise. Considering the uncertainties of the measurements, a good agreement between the results obtained by the three participating laboratories has been ascertained. However, in accordance with experimental results obtained by other authors, data reported by UC show a significant decrease of the radon emanation factor as moisture content of the sample decreases below 5% (per weight).

Keywords: Intercomparison exercise; Gamma spectrometry measurements; Natural radioactivity; Activity concentration; Radon emanation factor

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1. Introduction

Among the mechanisms of exposure to natural sources of radiation, two are mainly responsible for human exposure: external irradiation due to terrestrial gamma rays from naturally-occurring radionuclides in soils and building materials and, specially, internal irradiation from the inhalation of radon and its short-lived decay products which amounts to more than 50% of the total exposure. The great interest in the study of these natural radiation sources has led to many local, regional and national surveys on indoor radon and natural radioactivity worldwide, in the last decades. Nevertheless, few data are available about studies concerning intercomparisons of natural radiation and radioactivity measurements. In this sense, taking advantage of the experience accumulated with the two international intercomparisons of gamma spectrometry measurements of natural radioactivity carried out in the last years (Quindós et al., 1991, 1995), the Medical Physics Department of the University of Cantabria UC, Spain, has co-ordinated during 1998 a new intercomparison exercise on natural radioactivity and radon emanation factor measurements for a solid sample. This intercomparison has been organized and developed in the framework of the EU Concerted Action ERRICCA (European Research into Radon in Construction Concerted Action) to be carried out in the Nuclear Fission Safety Research and Training Programme under contract FI4P-CT96-0064 (DG 12-WSMN).

In addition to UC, two other laboratories involved in the ERRICCA have participated in the intercomparison exercise: Radiation and Nuclear Safety Authority STUK from Helsinki, Finland, and Institute of Occupational Safety ZVD from Ljubljana, Republic of Slovenia. The aim of this paper is to summarize the main results achieved in the aforementioned intercomparison.

2. Materials and methods

All the measurements in the intercomparison exercise, those of natural radioactivity as well as those of the radon emanation factor, have been made on a 'blue concrete' sample kindly donated by Dr Gustav Akerblom from the Swedish Radiation Protection Institute, Stockholm, Sweden. These bluish lightweight concrete blocks (approx. 600–700 kg m^{-3} density), commonly used until 1974 as building material in Swedish dwellings, were made of uranium-rich black alum shale, had a high gamma radiation level and were an important source of indoor radon.

The original 'blue concrete' block delivered by Dr Akerblom was crushed to pass through a 2-mm mesh sieve and then thoroughly mixed in order to obtain a fairly homogeneous sample. From this sample, three subsamples of 0.75 kg each, approximately, were prepared and sent to the participating laboratories.

Gamma spectrometry measurements of natural radionuclide activity concentrations were made using high purity germanium detectors, sample weights between 180 and 365 g and counting times ranging from 2.7×10^4 to 10^5 s. Before measurement, each sample was first dried in the oven over night at 105°C and then transferred to a radon tight container and left for at least 4 weeks in order to ensure that radioactive equilibrium between ^{226}Ra, ^{222}Rn and its short-lived decay products was reached. Gamma lines used for determining the activity concentrations of the different natural radionuclides studied were 92.6 keV for ^{238}U, 295.22, 351.92, 609.32 and 1120.28 keV for ^{226}Ra, 46.54 keV for ^{210}Pb, 911.07 and 968.9 keV for ^{228}Ac, 583.15 keV for ^{228}Th and 1460.75 keV for ^{40}K.

Concerning the radon emanation factor, only data from STUK and UC laboratories have been reported. At STUK the sample was first enclosed in a radon tight container for 25 days. After the first gamma measurement the container was opened, left open overnight and measured again on the next day with the same detector. Radon emanation factor was determined from the ratio of the net count rates from ^{214}Pb and ^{214}Bi gamma lines obtained in both measurements. At UC the evaluation of the radon emanation factor was made by using a method, developed in its laboratory, based on the principle of enclosing a small sample of the material to be tested in a hermetically sealed modified Lucas cell, designed and

Table 1
Intercomparison natural radionuclide activity concentrations and radon emanation factor results

	^{238}U (Bq kg^{-1})	^{226}Ra (Bq kg^{-1})	^{210}Pb (Bq kg^{-1})	^{228}Ac (Bq kg^{-1})	^{228}Th (Bq kg^{-1})	^{40}K (Bq kg^{-1})	Emanation factor
ZVD	1268 ± 43	1312 ± 33	1154 ± 43	33.2 ± 14.2	29.9 ± 10.6	831 ± 67	–
STUK	1242 ± 37	1470 ± 30	1020 ± 51	36.6 ± 7.6	28.8 ± 6.0	880 ± 53	0.17 ± 0.02
UC	1228 ± 53	1350 ± 30	1068 ± 47	32.2 ± 8.1	29.5 ± 7.4	816 ± 49	0.12 ± 0.01[a]
							0.20 ± 0.02[b]

[a]For a moisture content of 1.5% (per weight).
[b]For a moisture content of 4.3% (per weight).

built in UC, and measuring the radon concentration growth in the cell from which the emanation factor may be assessed (Quindós et al., 1994).

An important aspect of the intercomparison carried out was that no reference data were given to any of the participating laboratories which defined their own calibration procedures.

3. Results and discussion

Results obtained by the three laboratories participating in the intercomparison, along with their respective combined standard uncertainties, are summarized in Table 1. In particular, this table shows the weighted mean activity concentrations of the different radionuclides measured in the 'blue concrete' sample used in the intercomparison for all gamma lines analysed, as well as the values of the radon emanation factor found by STUK and UC. The emanation factor value given by STUK was evaluated on a sample which was at room humidity for 1 month, while those reported by UC were measured for moisture contents of 1.5 and 4.3% (per weight), the latter corresponding, as in the STUK case, to a sample kept at room humidity for 1 month.

Considering the uncertainties of the measurements in Table 1, a small disequilibrium in the ^{238}U decay chain and, in general, a good agreement between the results obtained by the three laboratories participating in the intercomparison can be ascertained, except for ^{226}Ra activity concentration determined by STUK, which systematically shows values approximately 10% higher than those measured by the two other laboratories for all gamma lines analysed. However, in accordance with experimental results obtained by other authors (Stranden et al., 1984; Andersen, 1998), data reported by UC show a significant decrease of the radon emanation factor as moisture content of the sample decreases below 5% (per weight). It must therefore be concluded that it is absolutely necessary to develop a standard protocol for the evaluation of the radon emanation factor in porous samples to ensure the reliability of measurement results.

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